CANADIAN HARD SPRING WHEAT

Breeding and Testing New Varieties

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THE CANADIAN WHEAT BOARD

WINNIPEG, CANADA

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Breeding and Testing New Varieties

The outstanding and most valued characteristic of high-grade Canadian hard spring wheat is its dependability. Wherever it is known, it is bought and used by millers with complete confidence. Although export shipments out of Atlantic and Pacific ports are drawn from very large areas, their basic qualities remain the same from month to month and year to year. The fundamental reason for this uniformity is that the required qualities are bred into every variety of wheat that is licensed for use as seed. No variety can become established unless it carries the genes for those unique milling and baking qualities on which the reputation of Western Canadian wheat has rested for more than half a century.

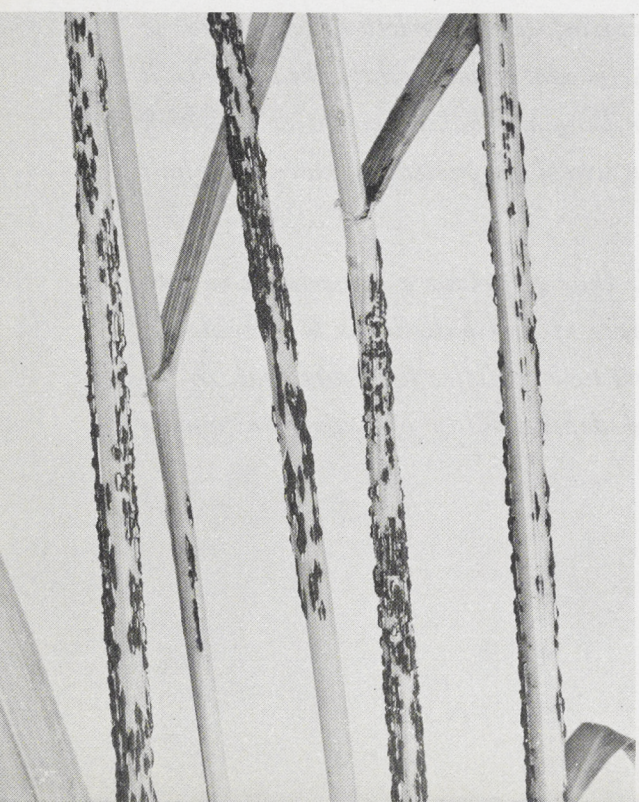
The breeding of new varieties is thus of primary importance to both growers and buyers, and the purpose of this bulletin is to provide an account of the system used in testing new varieties to ensure that, in the years ahead, the high quality and dependability of export shipments will continue to be maintained.

THE NEED FOR NEW VARIETIES

WHEAT BREEDING is carried on continuously with the object of: (1) producing new varieties more resistant to diseases and better adapted to the soils and growing conditions in different parts of Western Canada, i.e., varieties which will give larger yields of higher grade grain; (2) combining with these improvements in agronomic qualities, improvements in milling qualities; and (3) achieving these gains while retaining the strength characteristics of the varieties now being grown.

Wheat growing on the Canadian prairies is exposed to a number of hazards. A serious menace in the eastern half of the area is stem rust. The spores of the fungus causing this disease do not live through the severe winters, but fresh supplies are carried into the area each summer by southerly winds. The number of strains of the stem rust fungus is indefinitely large, and occasionally a virulent strain that is new to the wheat fields of North America makes its appearance. One task of the plant breeder, therefore, is to provide new varieties of wheat more resistant to the damaging strains of stem rust that have already appeared in western Canada, and so far as may be possible, resistant also to strains which may appear at some future time.

Other parasitic fungi attack the wheat plant causing other specific diseases with resulting losses in crop yield and grade. Among these are the numerous strains of the leaf rust fungus, and of the fungus which causes loose smut, as well as the micro-organisms responsible for a disease known as root rot. As with stem rust, the only effective means of controlling these diseases is to breed wheats more resistant to the more virulent strains of the fungi which cause them.



Wheat stem rust. There are many strains of the fungus causing this disease, and occasionally a new and virulent form makes its appearance. One of the primary objects of the wheat breeder is to produce new varieties with maximum resistance to the attacks of threatening forms of the fungus.

In the drier areas of southern Saskatchewan and Alberta wheat varieties must be grown which possess an inherited resistance to drought; and for parts of these areas it was necessary to breed new varieties capable of withstanding attack by the wheat stem sawfly. For the more northerly sections, where the growing season is short, an early ripening variety is essential to minimize the danger of damage by late frosts in the spring and, more especially, by early frosts in the autumn.

The efforts to produce new wheat varieties, better able to meet these various hazards, have no end. But it is important to emphasize that no matter what the goal of any particular breeding project may be, it must be attained, if attained at all, without any sacrifice of those milling and baking qualities which have given Canadian wheat its world-wide reputation. If there are some gains in one or more components of this complex of qualities—as indeed there have been—so much the better; but there must certainly be no loss.

THE BREEDING OF NEW VARIETIES

THE STARTING POINT of any breeding program is, of course, the parent material. Since the breeder cannot as yet create or modify genes to suit his requirements, he must choose parents already endowed with the genes for the qualities he wants in the new varieties. And because the offspring must be adapted to growing conditions in Western Canada and, above all things, must possess qualities characteristic of the wheat from that area, one of the parents will be a typical Canadian variety; the other will be the carrier of the gene the plant breeder wishes to confer

Making a cross. In the wheat heads shown here the anthers have been removed from the flowers to prevent self-pollination. Ripe anthers (at the base of the thumb) from the variety chosen to be the male parent of the new hybrid, are being broken over the stigmas of the emasculated flowers. Each resulting seed will carry the genes of both parent varieties.

on the Canadian variety—for example, the gene for resistance to a particular strain of stem rust. To find this gene he may have to go far afield. Fortunately there is now available a fund of information regarding the fungi which cause wheat diseases in different parts of the world, and about the resistance to these micro-organisms possessed by wheat varieties grown in most countries. For several years Canadian workers have also been conducting a systematic study of the milling, baking, and other qualities of potential parent-material from many sources. From an examination of such records the plant breeder will decide which particular wheat to cross with the Canadian variety.

The method used in crossing wheat varieties is conditioned by the fact that wheat flowers are bi-sexual and normally self-pollinated. It is as follows. Before they have shed their pollen, the anthers are removed from the flowers of a plant that is to become the female parent and a cover is slipped over the emasculated wheat head to exclude foreign pollen. Two or three days later the cover is taken off, and a ripe anther, removed by means of forceps from the other parent plant, is broken over the stigma of each emasculated flower. The cover is replaced and the cross-fertilized egg-cells now develop into grains which usually mature a little more than a month later. This method of producing new wheat varieties has been used for about a hundred years and was first adopted in Canada as early as 1888.

Examining heads containing seeds produced by crossing as shown in Fig. 2. To speed up the breeding work the cross was made in a growth chamber where temperature and lighting are controlled. Note the fluorescent lights in the ceiling.

Selection of disease-resistant wheat hybrids in a greenhouse. The second generation progeny of the crossed seeds consists of many thousands of plants. Most of them—98% or more—are immediately rejected for one fault or another. The process of selection goes on generation after generation.

PRELIMINARY TESTING OF NEW VARIETIES FOR VIGOR, DISEASE RESISTANCE AND OTHER CHARACTERS

LET US SUPPOSE that the skilled plant breeder has selected the parents, made the cross, and gathered the hybrid seed. On sowing this seed in the hybrid nursery, the first generation plants, having the same inheritance, will be much alike in appearance and thus offer no scope for selection. In the second generation, however, ten to twenty thousand plants, or more, will be obtained; and these, especially if the parents were widely different, will consist of many types which differ from one another in one or more characters. Most of these plants—98% or more—will be almost immediately discarded, either because they lack vigor, or fail to survive early tests for disease resistance, or produce seeds of poor appearance, or display some other fault.

In the next generation 25 to 75% of the remaining lines will probably be dropped, and the screening out of unsatisfactory lines will continue in each subsequent generation. Quality tests, which will be discussed later, are first applied in the fourth generation. Their use leads to the early rejection of lines which, whatever other advantages they may possess, have definitely poor milling qualities or yield flour with undesirable characteristics. Careful testing and selection over several generations are required to isolate the most promising lines resulting from any cross. In the typical case under consideration this will have been substantially achieved after plants and grains of the sixth generation have been examined.

TESTING NEW VARIETIES FOR FIELD PERFORMANCE

OF THE THOUSANDS of lines obtained at the second generation only a very few survive the early years of screening for appearance, vigor, disease resistance and quality. At the sixth generation these survivors begin a series of tests in field plots. All through the field tests the reactions of the hybrids to disease continue to be critically studied; information is accumulated about their agronomic characteristics—yield, earliness, strength of straw, etc.; and baking tests are included in the tests for quality. After the first two years of field testing the survivors, now probably numbering only two or three, together with surviving hybrids obtained from other crosses, enter what are called "Co-operative Wheat Tests", in which the new varieties are grown alongside standard varieties at more than twenty stations well distributed over Western Canada. The trials are carried out under the expert supervision of cerealists and plant pathologists, and are carefully designed to give reliable comparative data as to yield per acre and other characteristics of agronomic importance, disease resistance, insect resistance, and quality. In order to gain acceptance, a new variety must perform for three seasons to the satisfaction of a committee of specialists but may be dropped at the end of any one of the years if it fails to give satisfactory results. Any successful variety can be depended upon to possess adequate disease resistance, to be capable of doing well in the part of Western Canada for which it was designed, and also, as we shall see in the next section, to possess milling and baking qualities at least equal to those of the standard variety, Marquis.

Experimental plots of hybrid wheats.

Apparatus for inoculating wheat heads with spores of the fungus which causes the disease known as loose smut.

TESTING NEW VARIETIES FOR QUALITY

As Already Noted, the testing of hybrids for quality begins with the grain of the fourth generation. Such early tests, when the quantity of grain available is necessarily quite small, only became possible with the development of micro-milling equipment. With this equipment samples weighing 40 to 100 grams (or more) can be successfully milled. From the character of the bran, and the percentages of flour obtained, a good opinion can be formed of the milling qualities of the small samples. The flours themselves are substantially free from bran and germ and can be satisfactorily used for one or more screening tests for quality. The tests usually applied, depending upon the quantity of flour at the chemist's disposal, are protein, the Zeleny sedimentation test, a dough expansion test, and the mixograph test. By using these methods it is possible to eliminate a number of hybrids which mill poorly or yield flour of unsatisfactory quality, without having to multiply them through later generations in order to produce samples sufficiently large for full-scale quality tests.

When, at about the sixth generation, the surviving hybrids are transferred from the nursery plots for field testing, sufficiently large samples (about 1 kilogram) are obtained to allow milling tests to be done on laboratory mills of standard size. At this point, baking tests are added to the other flour quality tests.

Full scale tests for quality are carried out on the wheats produced in the Co-operative Trials. It will be remembered that in these trials new varieties and standard varieties—one of which is Marquis—are grown at more than twenty stations. The resulting samples of each variety are composited and portions of each composite are sent to the Grain Research Laboratory in Winnipeg and the laboratory of the Research Branch of the Canada Department of Agriculture in Ottawa. In each of these laboratories the following information is obtained on the wheat samples:

Bushel Weight, Moisture, Protein, Ash, Flour Yield.

On the flours the following determinations are made:

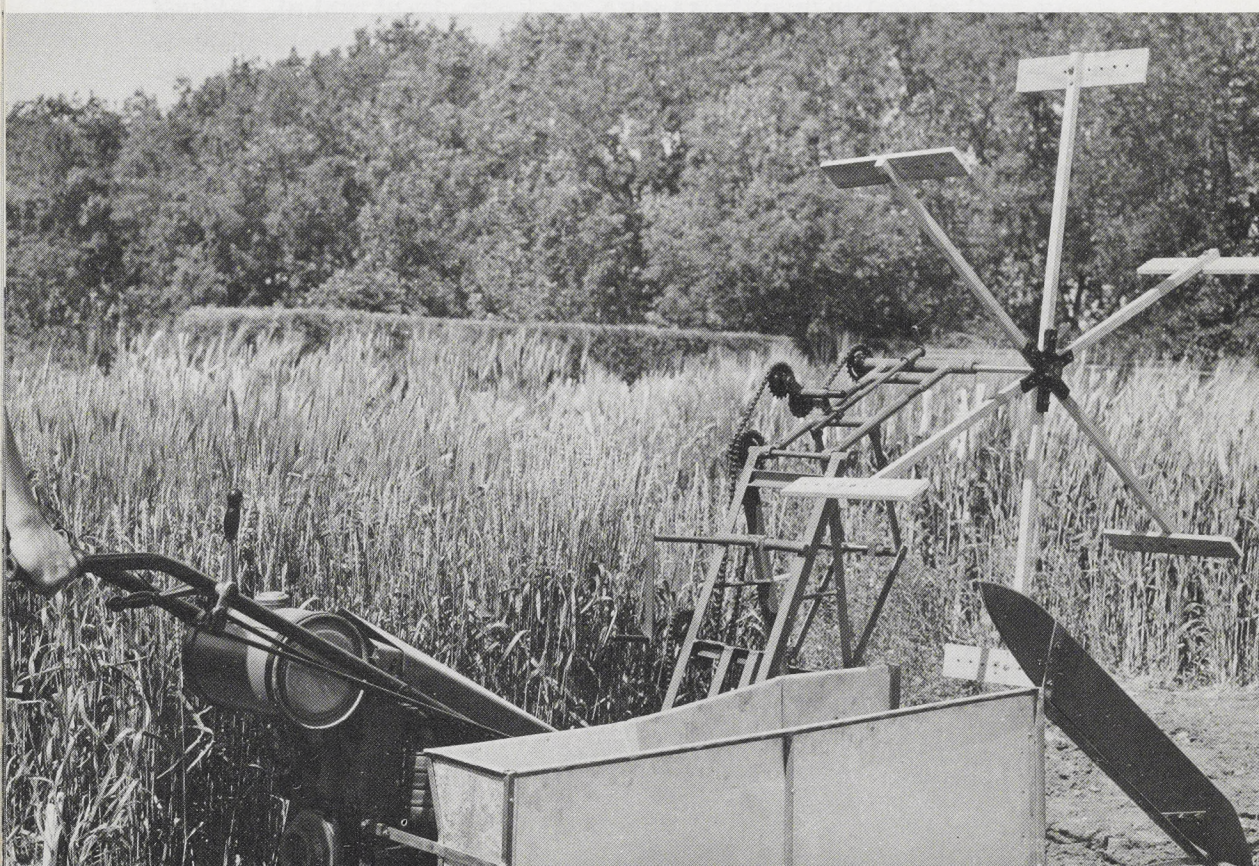
Moisture, Protein, Ash, Color Grade, Pigment.

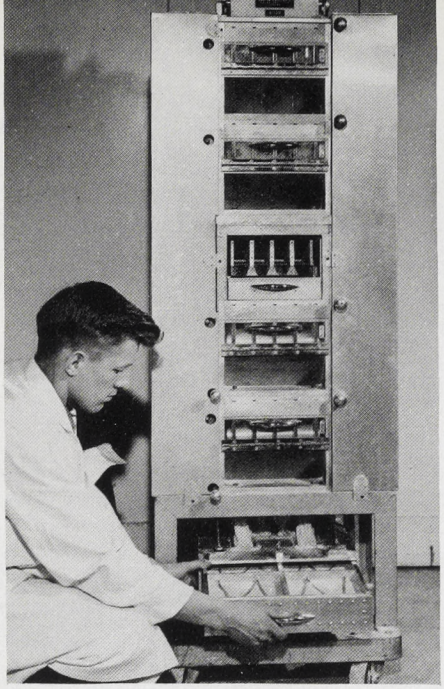
Physical dough tests are also carried out on the flours using the farinograph, the extensograph and the mixograph, and measurements are reported to define the characteristics of the curves obtained. Farinograph absorption results are also given.

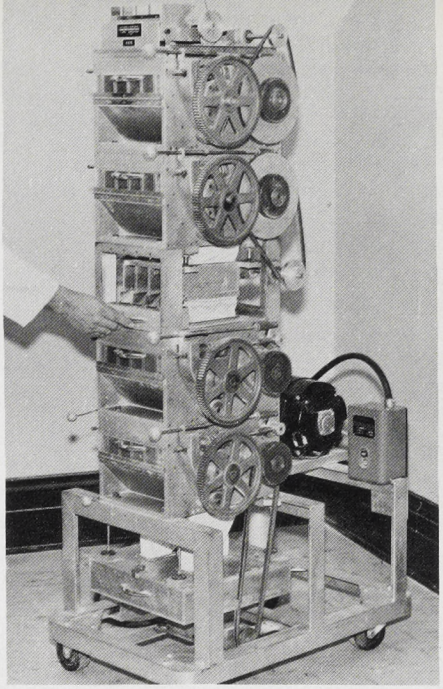
Finally the flours are baked by several standardized methods, selected to bring out the potentialities and shortcomings of the samples.

These exhaustive tests are repeated each year a new variety remains in the Co-operative Trials, and each year all the records from both laboratories are carefully examined by a committee of cereal chemists. A variety may be rejected after one or two years as not equal in quality to Marquis, but only after it has given satisfactory results for three years can a new variety be judged to be equal to Marquis.

Harvesting the wheat from experimental plots.

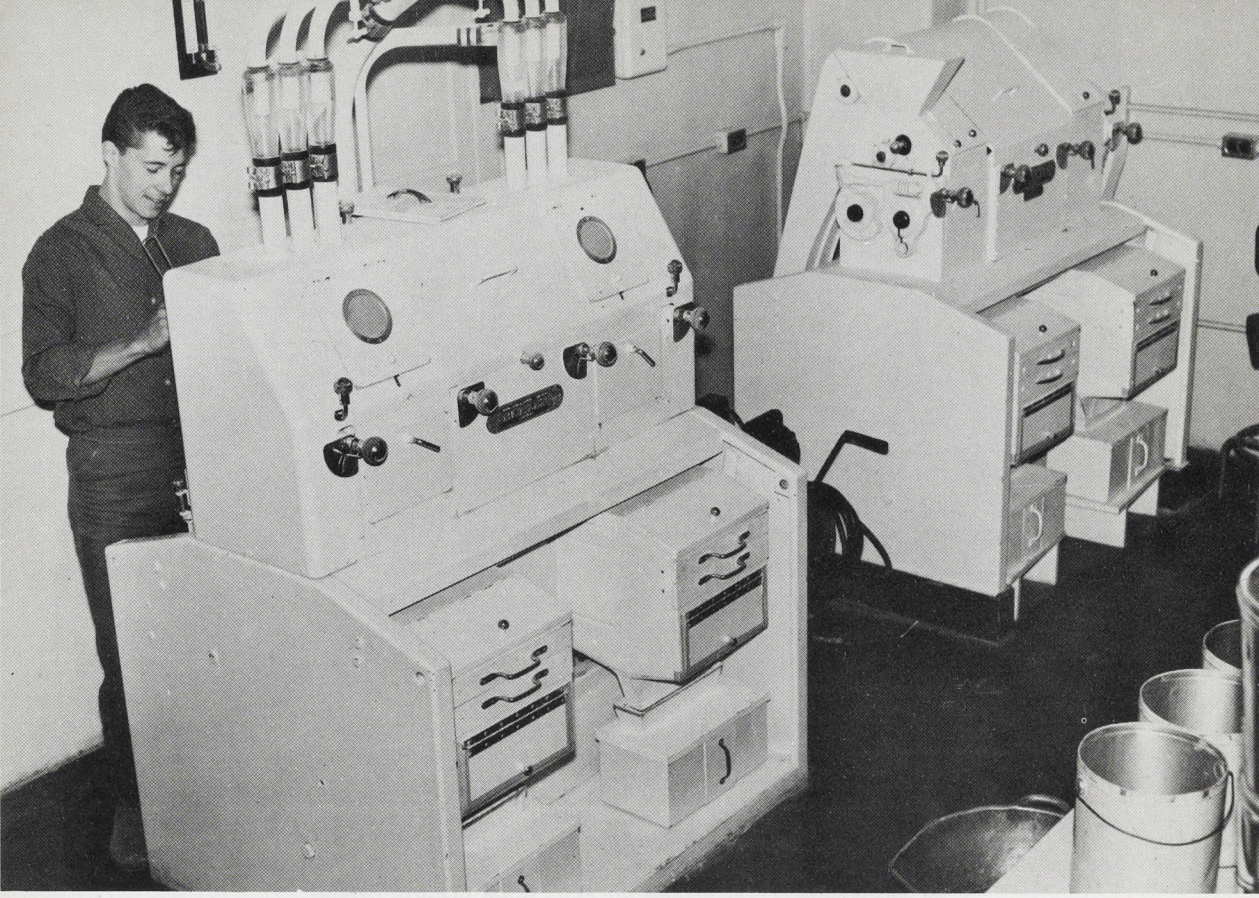






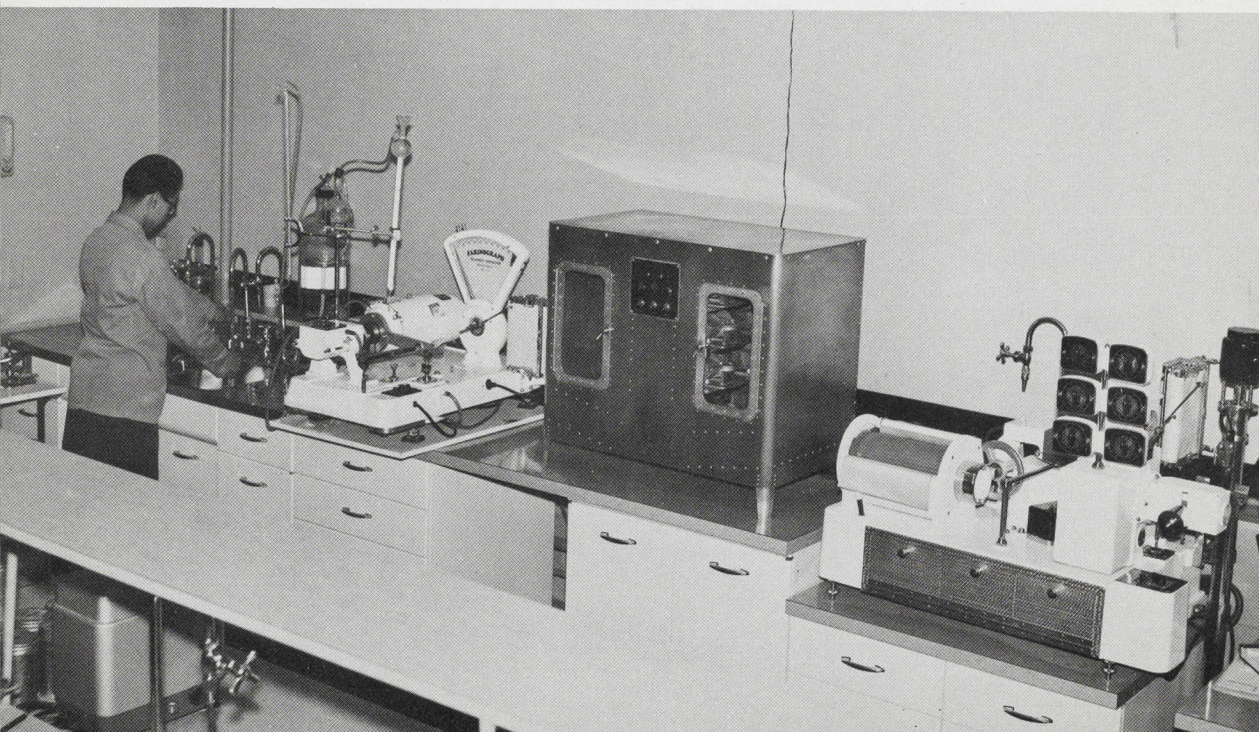
Micro milling equipment: left, in operation; right, with the casing removed to show the driving mechanism.
With this equipment four wheat samples, usually weighing 40-100 grams, can be milled simultaneously. The samples pass successively through two pairs of break rolls and the brans are removed by a small sifter. Two reductions follow. The flours separated by the lower sifter are weighed and then used for quality tests.

An Allis-Chalmers experimental mill in the Grain Research Laboratory, Winnipeg, where full-scale testing of new varieties is carried out. This mill has three stands of break rolls (corrugated rolls) and one stand of smooth reduction rolls.



Two Buhler laboratory mills in the Grain Research Laboratory, Winnipeg. The one on the left is a pneumatic mill.

Physical dough testing equipment in the Grain Research Laboratory, Winnipeg. On the left is a Farinograph which measures the changes in the physical properties of doughs during mixing. The Extensograph on the right measures the extensibility of doughs and their resistance to extension. Both are used in the testing of new wheats.

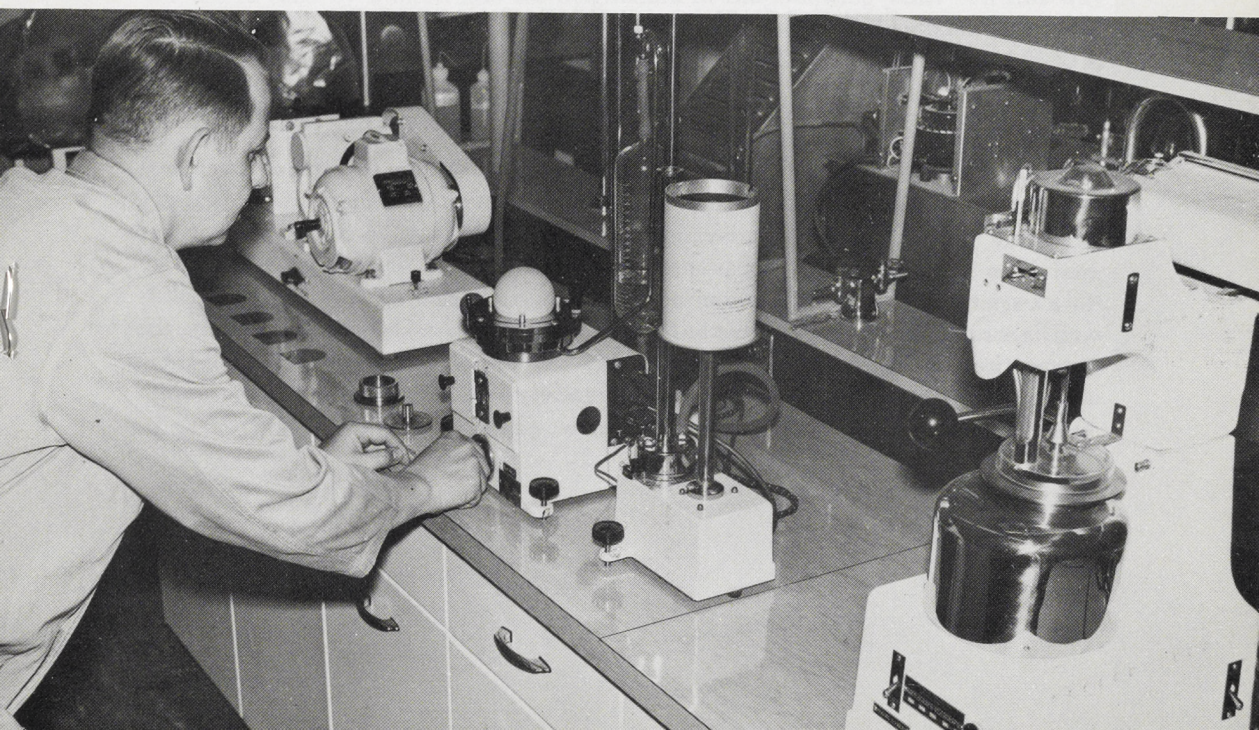


COLLABORATIVE TESTS FOR QUALITY

A VARIETY which, after three years in the Co-operative Trials, has gained the approval of plant pathologists, agronomists and cereal chemists, still has one more hurdle to surmount. For the final test it is grown with Marquis and perhaps two or three other new varieties at each of ten or more stations. Again the samples of each variety from these stations are composited and the large samples thus obtained are thoroughly mixed. Portions of the samples are sent to about twenty-five laboratories in seven countries (including Canada) where Canadian wheat is used and its properties are well known. Only the Marquis sample is named, the remainder being identified by code numbers. Each collaborator is asked to test the samples by whatever methods he prefers and to report: (a) his order of preference for the varieties; (b) the chief differences found between Marquis and each coded sample; and (c) whether he considers each of the coded samples to be satisfactory or unsatisfactory for his requirements.

The judgements reported are never unanimous; that could not be expected. Not only are the samples tested by a very wide range of methods and techniques, but collaborators, especially if they work in different countries, are bound to differ in their weighting of the many individual characters embraced under the term "wheat quality". In spite of this difficulty, studies of collaborators' reports have always provided clear-cut majority opinions which could be used with confidence by the Department of Agriculture in deciding whether a variety should be licensed for distribution as seed. In only one instance has a new variety, considered to be satisfactory after three years' testing in Canada, failed to gain approval in these international collaborative tests. As a consequence of this failure it was discarded.

Using a Chopin Alveographe. A sheet of dough is inflated by air to form a bubble, the inflation being continued until the bubble bursts. The air pressure within the bubble is continuously recorded on a moving sheet of graph paper and the characteristics of the curve thus obtained afford a measure of the strength of the flour.



The complete course of testing applied to hybrid material in a typical case has now been described. It can be summarized as follows:

TABLE I

TYPICAL COURSE OF HYBRID MATERIAL

Generation	Where Grown	Screening Tests Applied
Cross made	Field, greenhouse, growth chamber.	
1st Generation 2nd Generation 3rd Generation	Hybrid nursery.	Appearance, vigor, disease resistance, etc.
4th Generation 5th Generation	Hybrid nursery.	Quality testing begins.
6th Generation 7th Generation	Field plots.	Agronomic qualities. Testing for milling and baking qualities using laboratory equipment of standard size.
8th Generation 9th Generation 10th Generation	Co-operative Wheat Trials at over 20 stations.	Complete quality tests.
11th Generation	10 or more stations.	International collaborative tests.

THE LICENSING OF WHEAT VARIETIES AND THE PRODUCTION OF SEED

The Quality of Canadian wheat is safeguarded by a system of controls over seed production and distribution. In the first place, under Canadian law no variety of wheat may be imported, advertised, or offered for sale, as seed, unless it has first been licensed by the Department of Agriculture. A licence is granted only to a variety which: has undergone the full course of tests in Canadian field plots and laboratories as outlined in the previous sections; has been submitted to the international collaborative tests for quality; and has given such results in all these tests as to satisfy the authorities that the variety is of definite value to Canadian agriculture.

To protect still further the interests of the growers and users of Canadian wheat, the production of seed wheat is strictly regulated by the Government and the Canadian Seed Growers' Association. Seed of a licensed variety is supplied by the plant breeder to specially selected seed growers who grow it to produce a crop of "Foundation" seed. By multiplying foundation seed two other classes of pedigree seed grain are produced which are called "Registered" and "Certified" seed.

The growing, handling and selling of Registered and Certified seed are subject to a number of stringent regulations. These govern the previous use of the land on which the seed is grown and its isolation from all other crops, and they require that the seed crop, after it has headed and before it is cut, must be examined by a government inspector to establish its genetic purity. If the seed is to qualify for Registered status only 1 in 10,000 plants may be of another variety or off-type, while to qualify as Certified seed a maximum of 5 such plants is permitted. The seed producer is also required to take exacting precautions to prevent contamination when harvesting, handling and storing his crop.

Before seed, whether Registered or Certified, enters trade channels it is cleaned, and must then be graded by seed inspectors and analysts employed by the Department of Agriculture. The seed grade of a sample is determined by the number of weed seeds and seeds of other crops it contains, by the results of germination tests, and by its freedom from kernels damaged by such agencies as frost and bad harvest weather. Finally, under the supervision of a government inspector, tags are attached to the bags of seed wheat which assure the buyer that the seed was derived from plant breeder's seed; that the standing crop was inspected for varietal purity; and that the seed meets the standards for the seed grade shown on the tag.

This system ensures that pure seed of officially licensed and currently recommended varieties is made available to all farmers. Moreover, unlicensed varieties, and older licensed varieties that are no longer recommended because more suitable wheats have been developed, are not handled by the seed growers. In practice, many a farmer buys a few bushels of registered or certified seed each year to multiply for use as seed by himself and his neighbours in the following year. In this way the varietal composition of Canadian wheat crops is quickly influenced by the varieties of pedigreed seed produced by the seed growers. And these varieties, as already stated, are varieties that have been licensed and are currently recommended by agricultural authorities.

WHEAT VARIETIES LICENSED FOR WESTERN CANADA

VERY FEW NEW VARIETIES are successful in passing all the rigorous tests that have been described, so that the licensing of a new variety for sale as seed is a comparatively rare event. In the thirty-eight years since 1923 only twenty varieties of red spring wheat have been licensed for Western Canada. Several of these, after being grown for a few years in limited areas, have virtually disappeared.

The wheats now being grown are listed in Table II, which also shows the year each variety was licensed, and the percentage of the total acreage, seeded to hard red spring wheat in 1961, which was occupied by each variety:

TABLE II
DISTRIBUTION OF WHEAT
VARIETIES IN 1961

Variety	Year of Licence	% of Total (a) Acreage - 1961	Where Grown
Marquis	(b)	0.8	Alberta.
Garnet	1925	1.7	Limited areas in northern Alberta.
Red Bobs	1926	1.6	Alberta.
Thatcher	1935	52.2	Western Saskatchewan and Alberta except in extreme north and in sawfly areas.
Redman	1946	0.9	Rust area.
Rescue	1946	2.9	Wheat-stem sawfly area.
Saunders	1947	3.2	Northern areas.
Lee	1950	1.2	Rust area.
Chinook	1952	4.8	Wheat-stem sawfly area.
Selkirk	1953	27.1	Rust area.
Lake	1954	1.3	Dry area.
Pembina	1959	1.0	Intended for rust area.
Canthatch	1959	0.9	Intended for Thatcher area.
Miscellaneous	—	0.4	
		100.0	

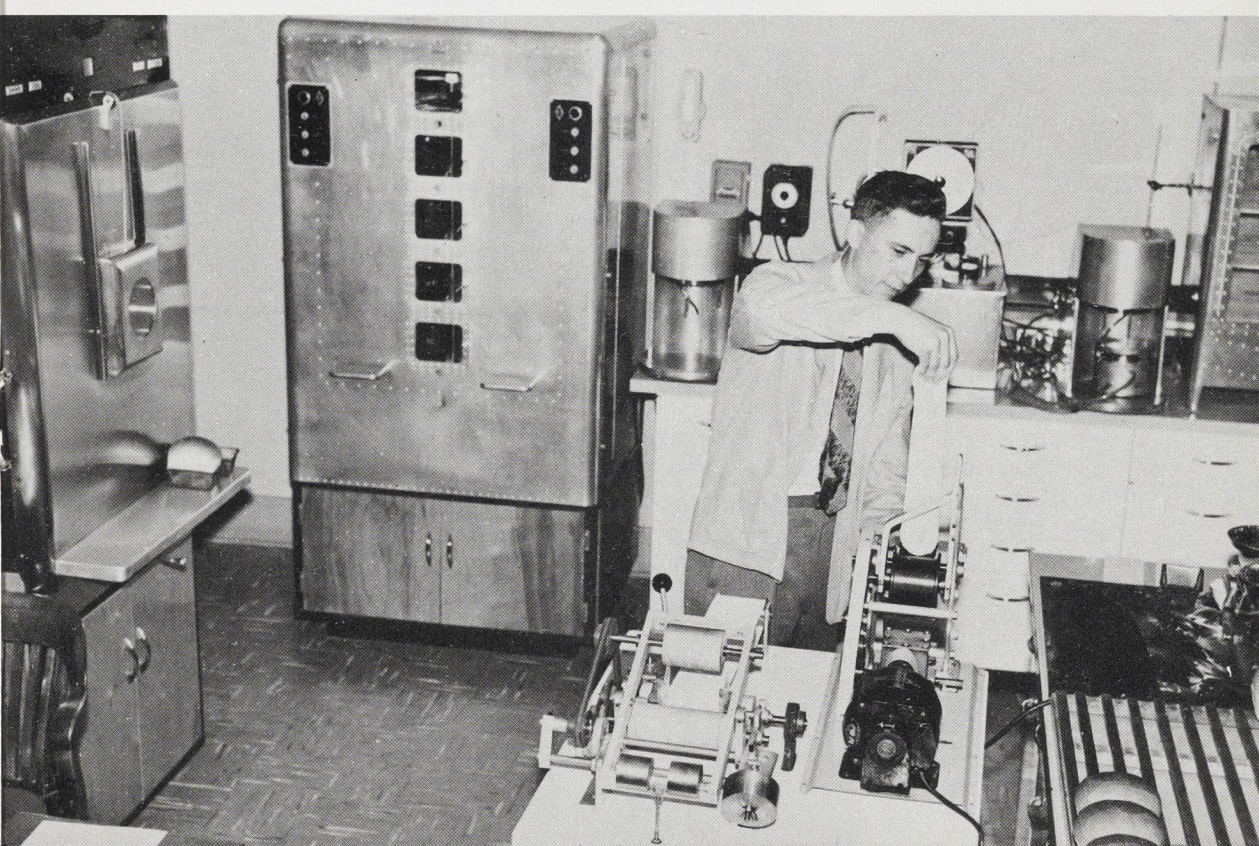
(a) "Total acreage" means total acreage seeded to hard red spring wheat.
(b) Marquis was released before licensing began.

All the varieties mentioned originated in Canada except Thatcher and Lee, which were developed in the United States. Thatcher has long been the dominant variety in Western Canada, and in 1961 a rather larger acreage was still seeded to this variety than to all others put together. The next most important variety is the rust-resistant Selkirk (27.1% of the acreage) and, following far behind, come the two sawfly-resistant varieties Chinook and Rescue (7.7%) and the early variety Saunders (3.2%). These five wheats occupied over 90% of the acreage.

Although the varieties have changed over the years, crops have always been largely made up, as in 1961, of one or two main varieties. From 1877, when the first export shipment was made, until about 1910, the dominant variety was Red Fife, a wheat of European origin. Red Fife had excellent milling and baking qualities but was rather late in ripening and often suffered serious damage from early frosts. It was replaced by the famous Marquis variety which matured six to ten days earlier and was more resistant to disease. Marquis had been produced by crossing Red Fife with a very early variety from India, and it is noteworthy that even at that time, the Canadian workers made the selection on the basis of milling and baking tests, as well as field performance. The development of this new variety was one of the first and greatest triumphs of scientific wheat breeding. Small samples of Marquis were distributed for seed in 1909 and, because of its advantages, its use spread with great rapidity. A single head in 1904 became a North American crop of 250,000,000 bushels in 1916; and in 1919 it occupied as much as 90% of the wheat acreage in Western Canada.

Marquis held a dominant position for about twenty years until its place was taken by Thatcher. Before it was licensed, four years of testing in Canada had shown Thatcher to be an earlier wheat than Marquis, which was one of its progenitors. It was also found to give good yields under a wide variety of growing conditions, and to possess milling and baking qualities which were generally considered to be somewhat superior to those of Marquis. Since 1939 Thatcher has been Western Canada's most important variety, although in recent years it has been displaced in Manitoba and eastern Saskatchewan by Selkirk which, unlike Thatcher, is resistant to the newer strains of stem rust.

Test baking in the Grain Research Laboratory, Winnipeg. Here a dough is being passed between the sheeting rolls. Next to the sheeting rolls is the mechanical moulder.



A view of the baking laboratory showing the ovens. Tests are done under carefully controlled conditions and all essential operations are fully mechanized.

THE VARIETAL UNIFORMITY OF EXPORT SHIPMENTS

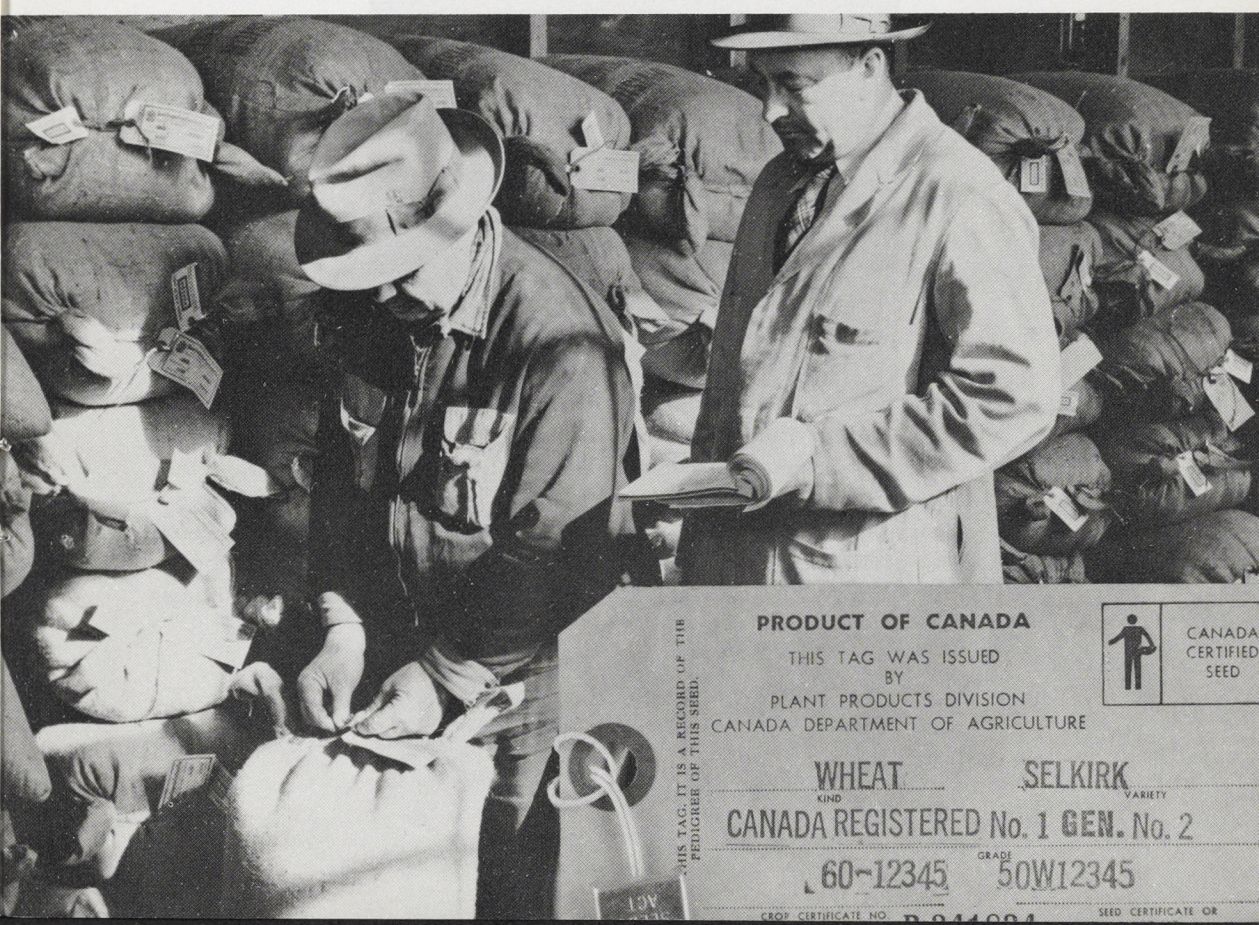
THE RAPID ADOPTION of a new variety is encouraged by the progressive spirit of the farmers on the one hand, and on the other by excellent facilities for the dissemination of agricultural information and an efficient system for the production, and distribution at moderate prices, of seed grains of high purity. The predominance of one or two varieties for periods of many years is brought about by the relative uniformity of growing conditions on the Canadian prairies. In turn, the fact that over long periods export shipments are so largely made up of so small a number of varieties, tends to make them more uniform in quality. All the varieties listed in Table II, except Garnet and Red Bobs, conform to type and are of good quality; otherwise they would not have been licensed. This is not, however, the same as saying that their qualities are identical. Comparative milling and baking tests would, indeed, reveal small varietal differences. But, since export shipments are largely made up of only one or two good varieties, the effects from a practical point of view of their small varietal differences become of no significance whatever. This is in contrast with other wheats entering world trade, for these may vary from one lot to another because shipments are made up of varying proportions of many different varieties, which differ widely from one another in quality.

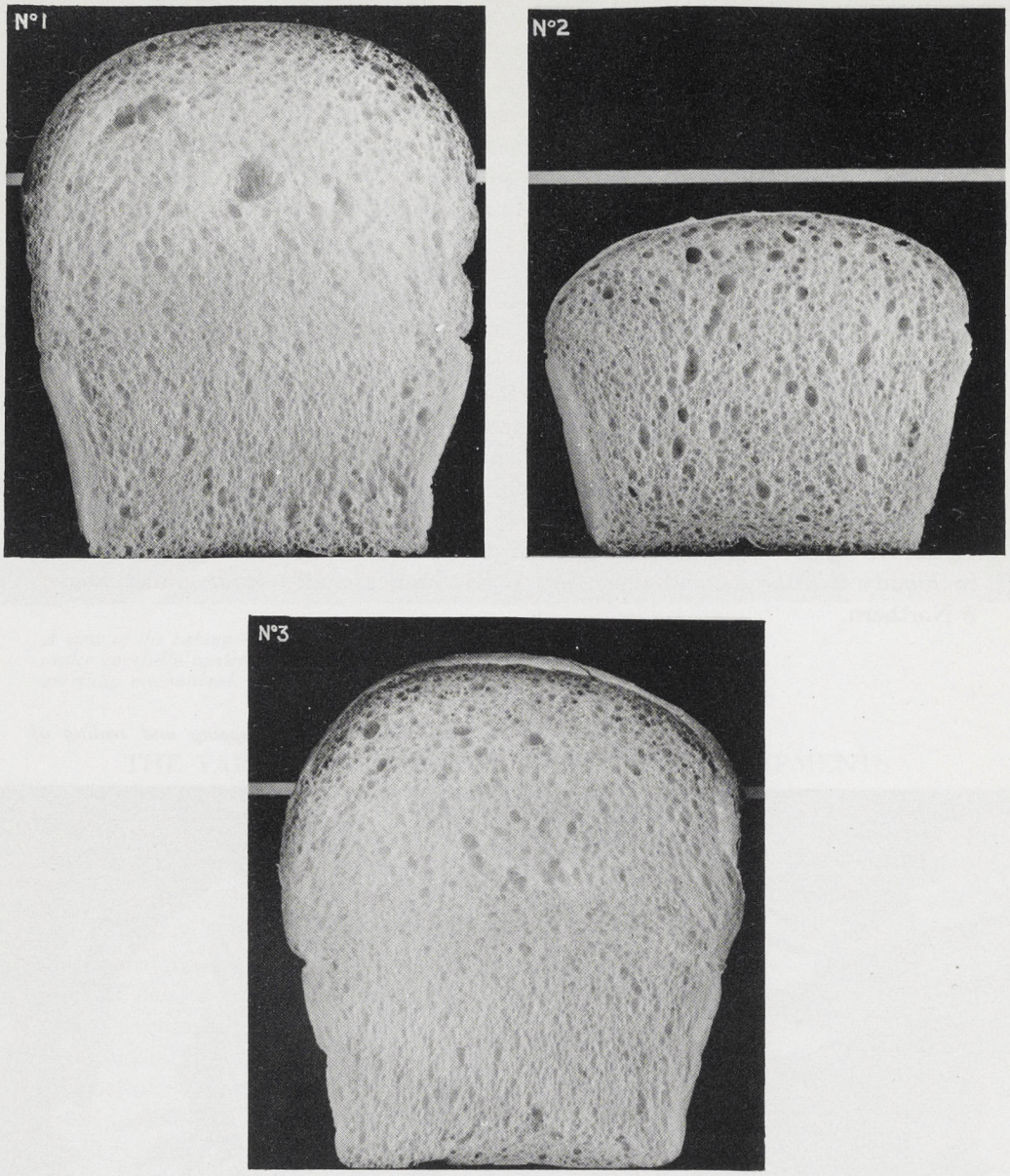
VARIETIES AND THE CANADIAN GRADING SYSTEM

THE CANADIAN GRADING SYSTEM is also applied to protect high-grade wheat from the infiltration of off-type varieties. Because of our tradition it is now almost impossible for a new variety, inferior in quality to Marquis, to be licensed for sale as seed. But if this should occur, or if a farmer should choose to grow an unlicensed variety, then the grading rules come into play to exclude the inferior wheat from the top grades, which means that the grower cannot get top price for his crop no matter how attractive it may look. The growing of varieties which are not equal to Marquis in quality, and therefore cannot enter the higher grades, is thus very effectively discouraged.

Two of the varieties listed in Table II are discriminated against by the grading and pricing system. Garnet, a very early wheat, licensed as long ago as 1925, goes into separate grades of its own which have usually sold at a substantial discount. It only continues to be grown in a few northern districts where frost is a very real hazard. The other variety is Red Bobs which was licensed in 1926. Extensive tests subsequently indicated that this wheat was slightly inferior in quality to Marquis and since then it has been excluded from grades above 3 Northern.

A government inspector supervising the tagging and sealing of registered seed. Inset—a tag and seal.





A successful cross. Loaf No. 1 was baked from Thatcher and Loaf No. 2 from Kenya Farmer, a rust-resistant wheat having poor baking qualities. The plant breeder crossed these two varieties in 1951 and from the resulting hybrids selected a new variety, which was named Canthatch, and licensed for sale in 1959. As will be seen from Loaf No. 3, Canthatch possesses the good baking qualities of Thatcher. From Kenya Farmer it inherited resistance to certain strains of stem rust to which Thatcher is susceptible.

SUMMARY

(1) In the breeding of wheat varieties better adapted to the needs of prairie growers, the necessity for maintaining the reputation of Canadian wheat for quality in world markets is regarded as of supreme importance and has been so regarded for sixty years.

(2) No variety can be offered for sale as seed until it has been licensed, and no new wheat is considered for licensing until it has passed the preliminary screening tests for quality, and then been tested for milling, baking and other qualities for six years. In the last year, collaborative quality tests are carried out on an international scale. That a variety inferior in quality to Marquis should be licensed is now virtually impossible.

(3) The grading system provides a further protection of quality standards. It discriminates against varieties inferior to Marquis and thus discourages their use by farmers.

(4) The growing of good varieties is promoted by the ready availability of pure seed at reasonable prices.

(5) Because climatic conditions are much the same from one district in Western Canada to another, one or two varieties generally constitute the great bulk of any crop. It is usual for a dominant variety to retain its position for a period of many years.

(6) As export cargoes are made up largely of one or two varieties, and good quality is bred into all varieties, differences in the varietal composition of export shipments have a negligible effect.

(7) Natural conditions in Western Canada favor the production of strong spring wheats, but it is only the combined effort of several groups of highly-trained workers that guarantees the high quality and uniformity of export shipments. The aims of these groups and of the responsible authorities remain unchanged and their work grows, if anything, more effective as time goes on. With this in mind, we can confidently predict that high-grade Canadian hard spring wheat will maintain its reputation for complete dependability as it has done in the past.

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